Quantification of Saturn and Enceladus tidal dissipation by astrometry after Cassini

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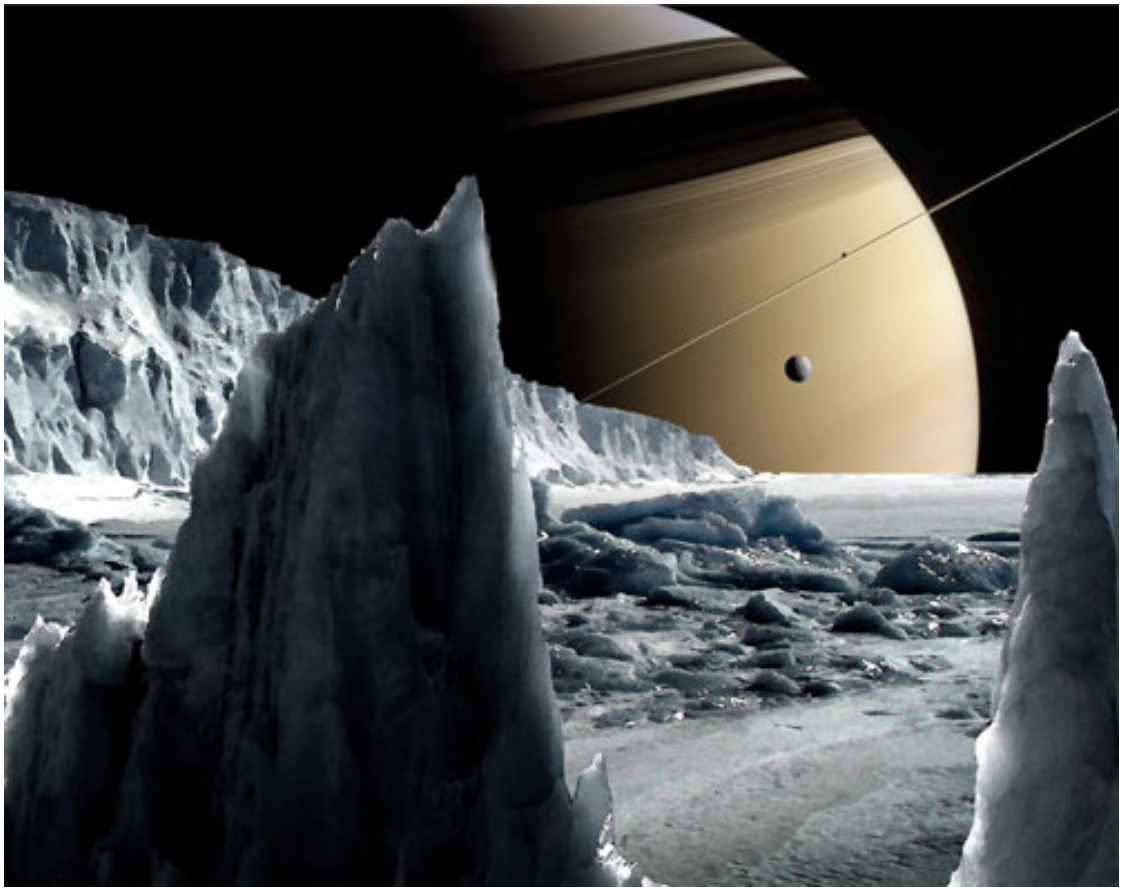
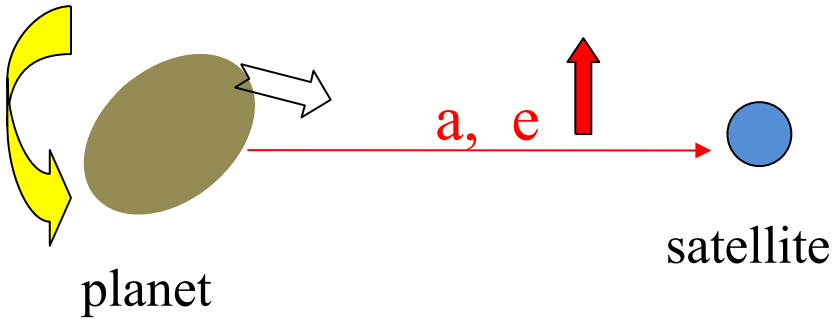


Jean-Eudes Arlot, Nick Cooper, Jean-Pierre De Cuyper, Véronique Dehant, Josselin Desmars, Tristan Guillot, Robert A. Jacobson, Christophe Le Poncin-Lafitte, Stéphane Mathis, Carl Murray, Dan Pascu, Françoise Remus, Vincent Robert, Radwan Tajeddine, William Thuillot, Gabriel Tobie, Jean-Paul Zahn

AGU, New Orleans, December 15th 2017

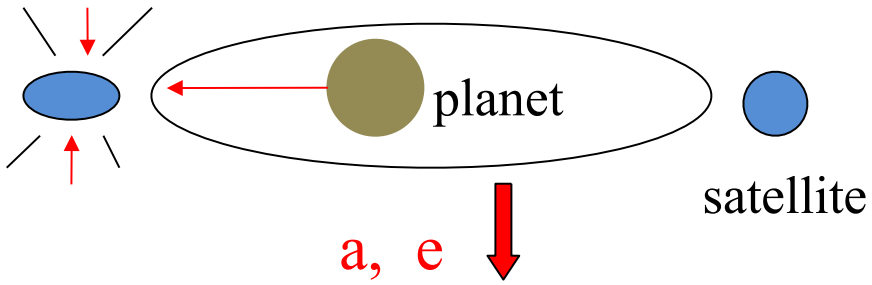
Linking Enceladus and Saturn: tidal effects

Tides in Saturn:



- Secular deceleration on the mean motion
- Heating inside Saturn

Tides in Enceladus:



- Secular acceleration on the mean motion
- Heating inside Enceladus

Linking Enceladus and Saturn: tidal effects

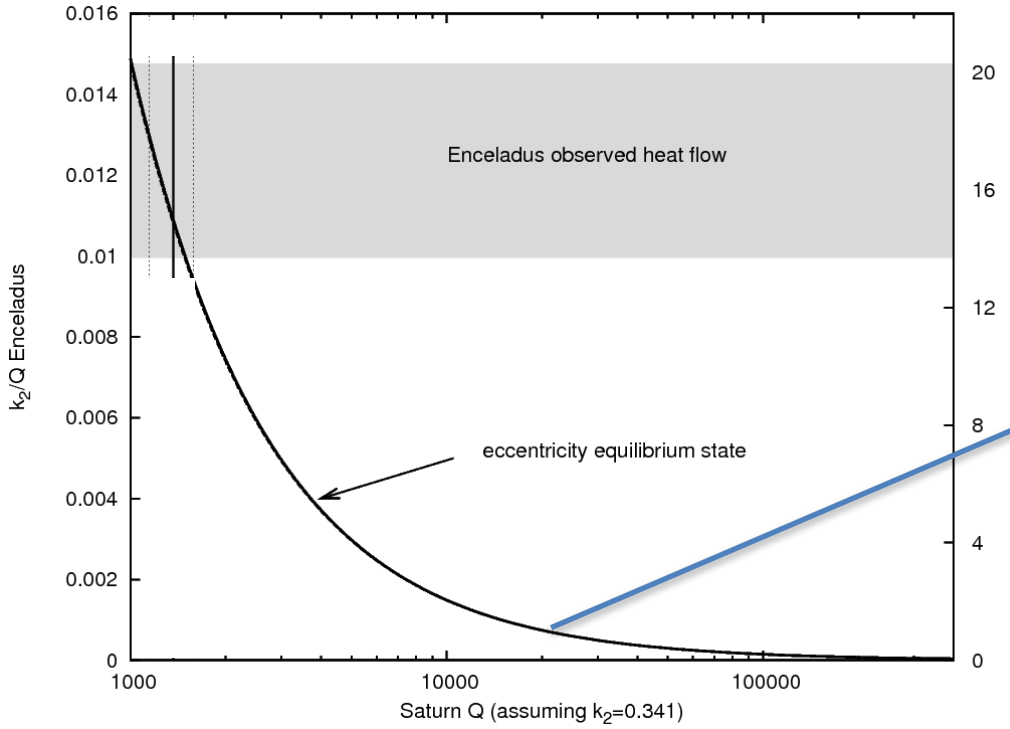
Meyer and Wisdom (2007) studied the orbital dynamics of the system Saturn-Enceladus-Dione.

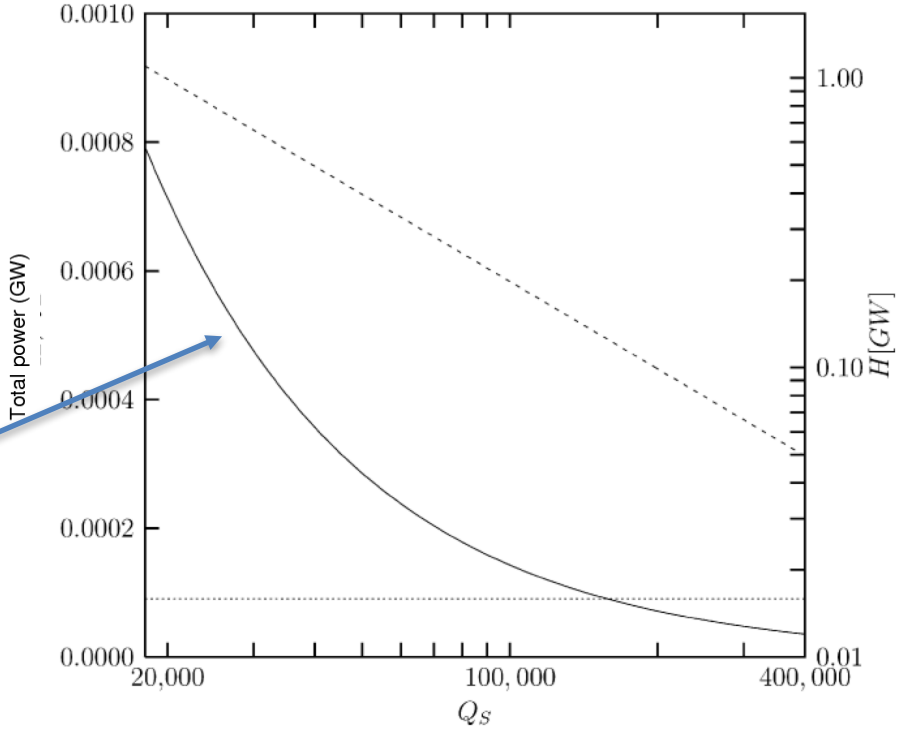
Maintaining Enceladus' eccentricity provides a relation between Enceladus and Saturn's tidal dissipation:

Eccentricity equilibrium

$$e^2 = \frac{1}{7D}\left\{1 - \frac{1 + m_1 a_0/(m_0 a_1)}{1 + (m_1/m_0)\sqrt{a_1/a_0}} + \left(\frac{m_1}{m_0}\right)^2 \left(\frac{a_0}{a_1}\right)^6 \left[\frac{n_1}{n_0} - \frac{1 + m_1 a_0/(m_0 a_1)}{1 + (m_1/m_0)\sqrt{a_1/a_0}}\right]\right\}$$

$$D = \frac{k_{2E}}{Q_E}\frac{Q_S}{k_{2S}}\left(\frac{M_S}{m_E}\right)^2\left(\frac{R_E}{R_S}\right)^5$$





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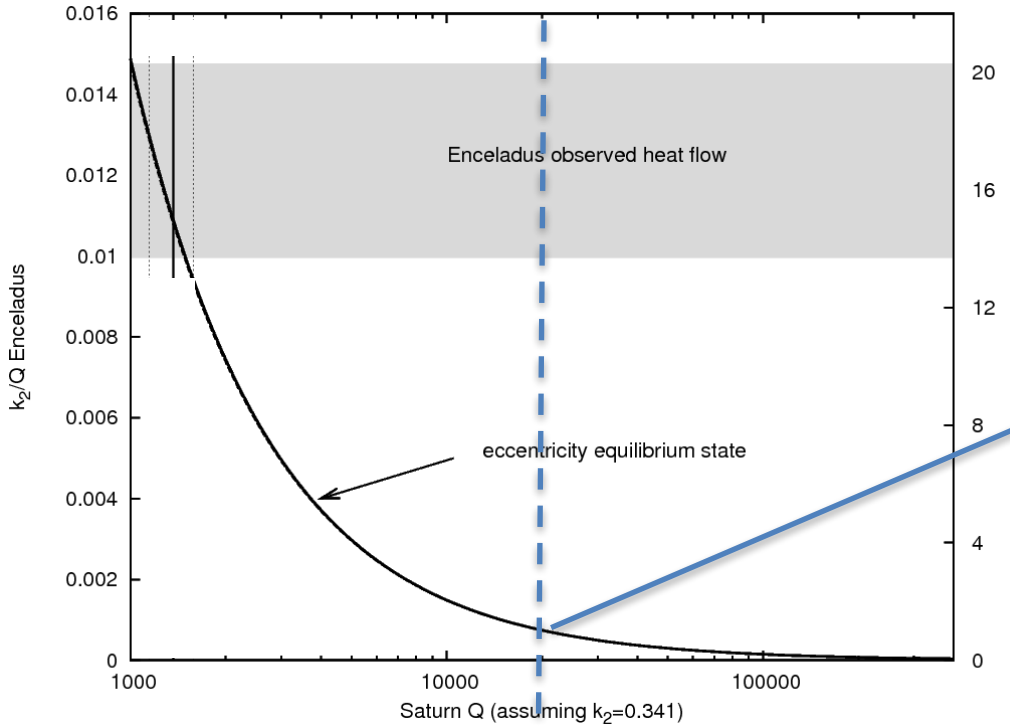

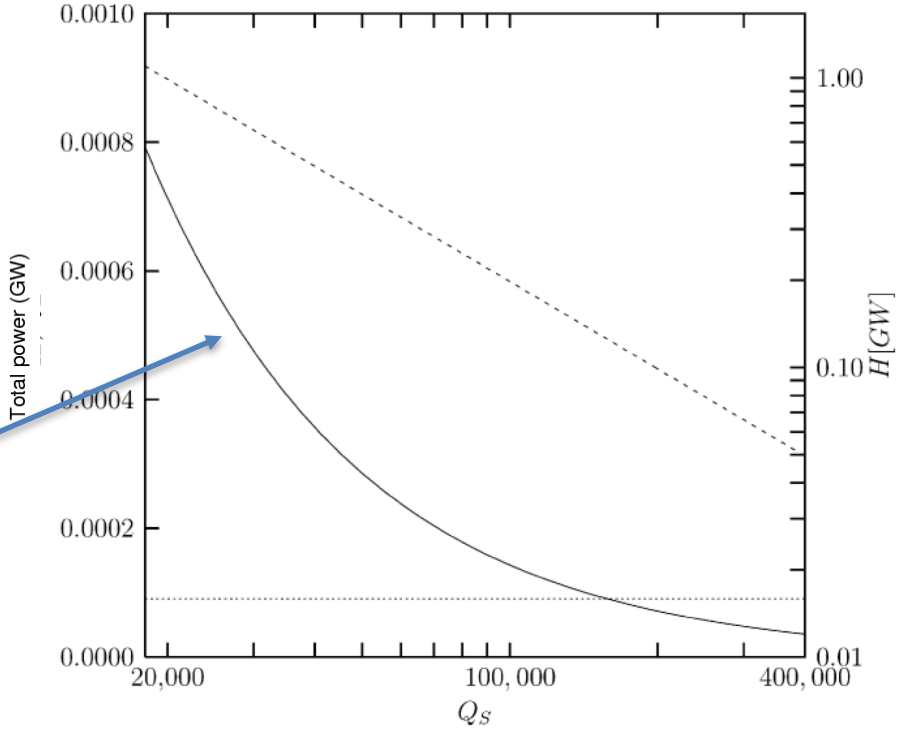

Sinclair 1983: $Q \leq 18{,}000$

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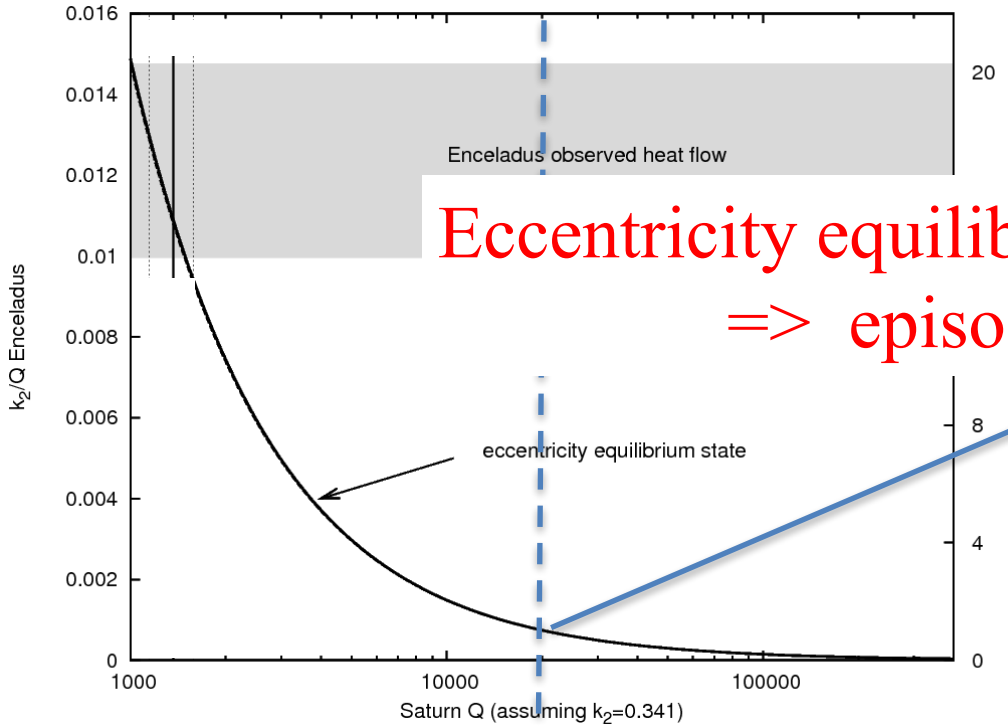
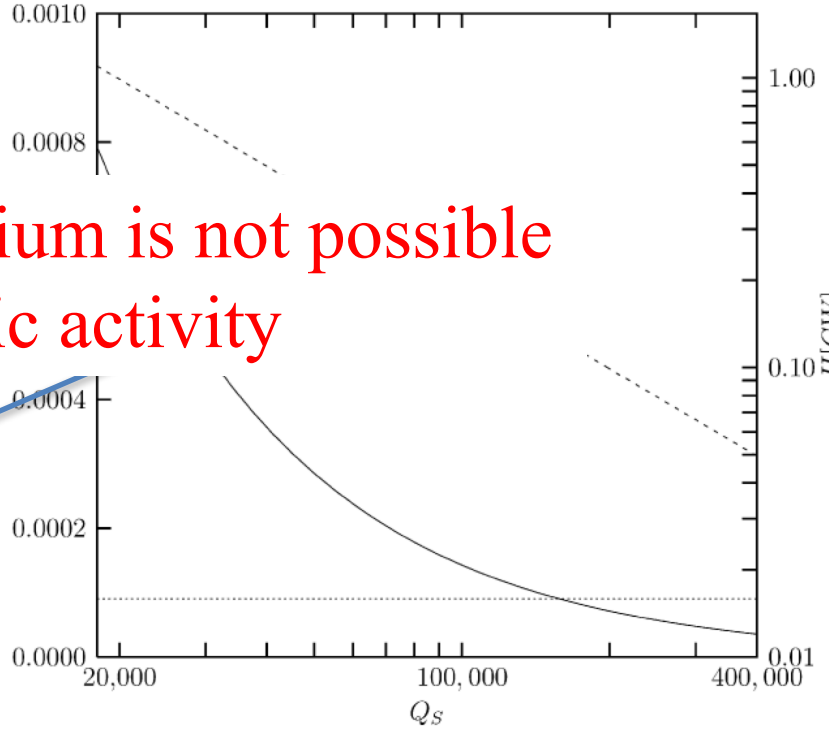


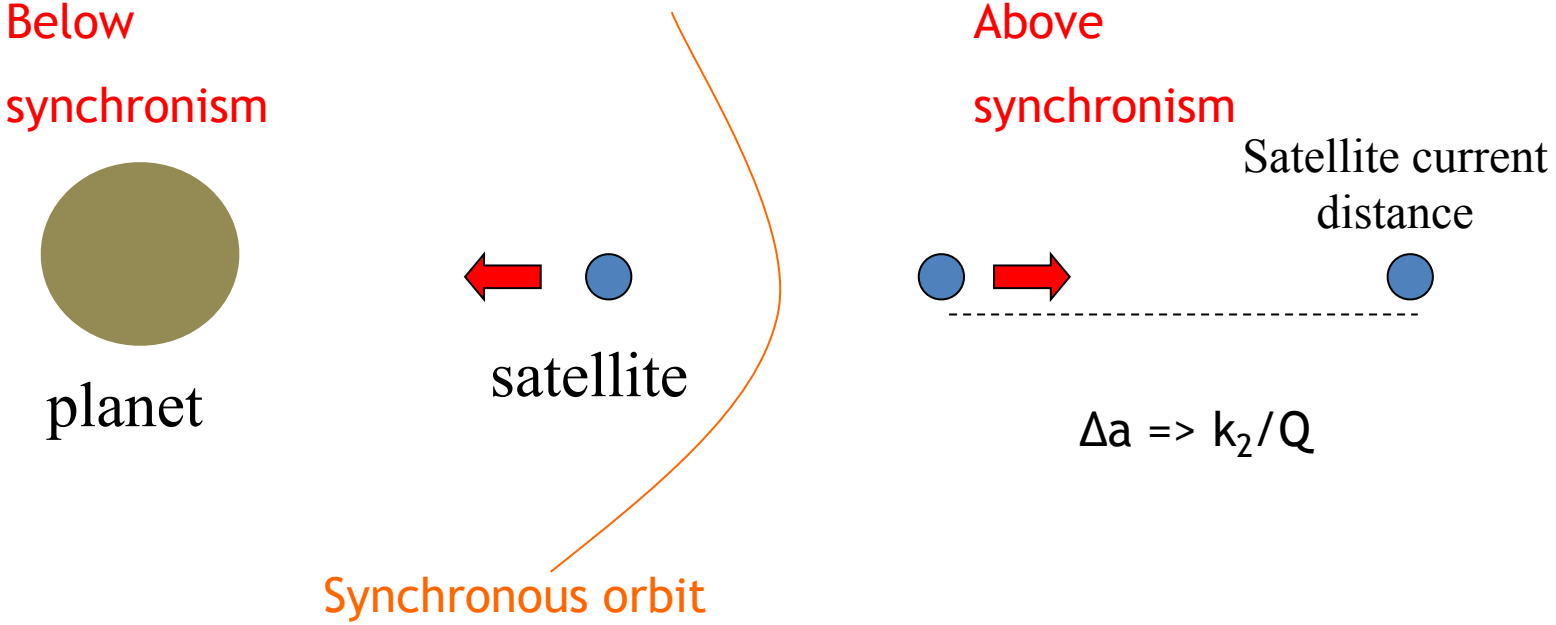


Eccentricity equilibrium is not possible
=> episodic activity

Sinclair 1983: Q ≤ 18,000

The origin of a presumably high Saturn's Q: Goldreich and Soter (1966)

Assuming that the main satellites were formed beyond the synchronous orbit, one can give a lower bound for Q using Mimas current position



Hypothesis:

- Mimas formed 4.5 Byr ago
- Saturn's k_2/Q does not change much as function of tidal frequency

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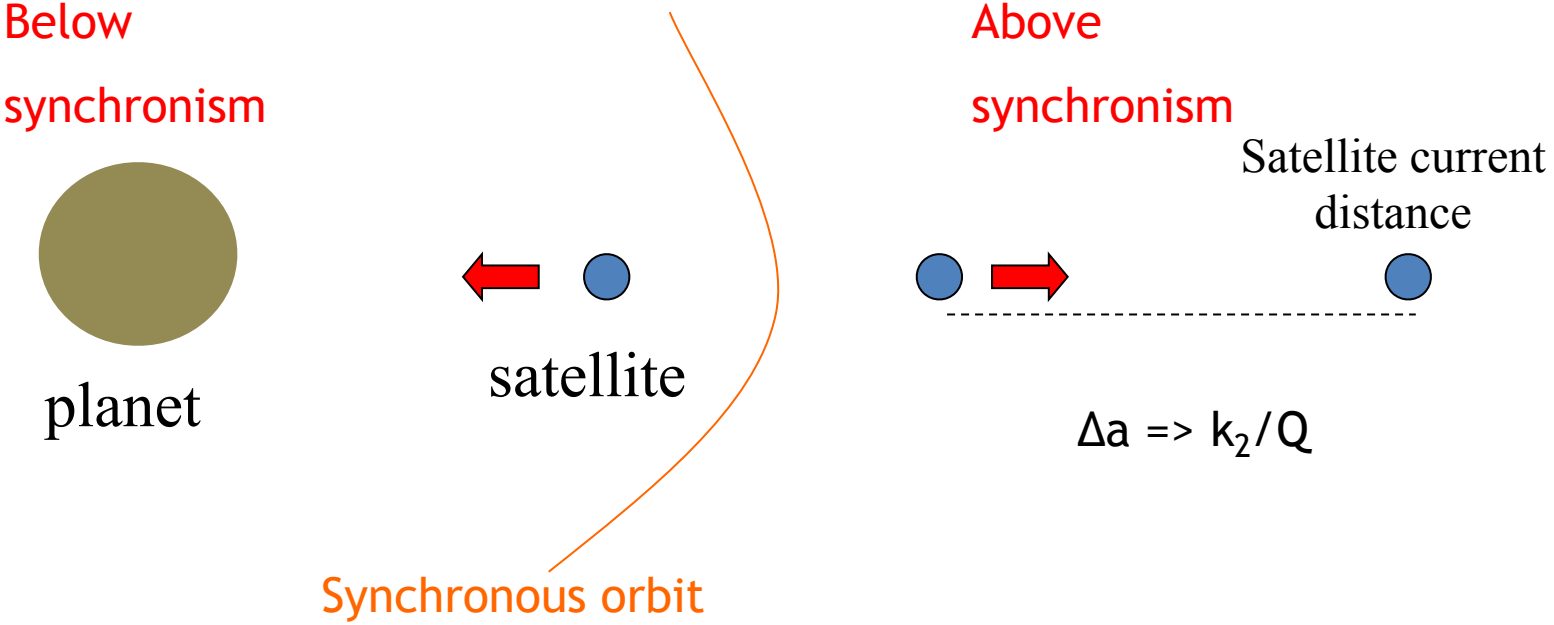


Charnoz et al. (2009): Mimas would not survive the LHB

Hypothesis:

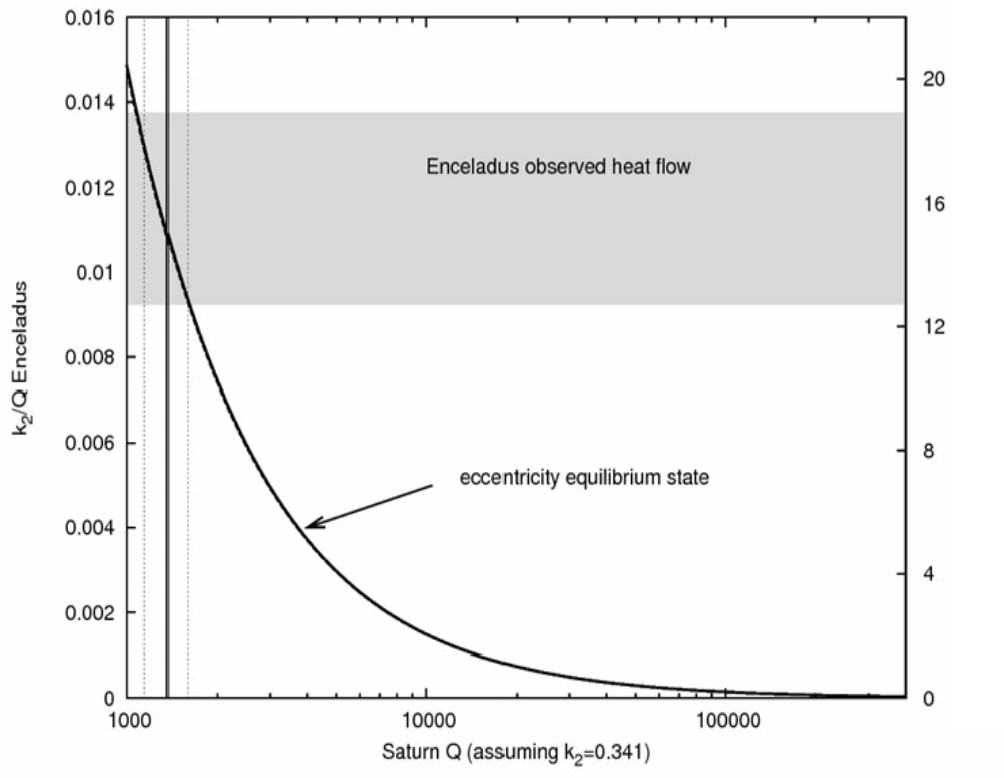
- Mimas formed 4.5 Byr ago
- Saturn's k_2/Q does not change much as function of tidal frequency

Wu (2004), … Fuller et al. (2016): k_2/Q may change drastically with frequency

First estimations of Saturn's tidal k_2/Q from astrometry:

Using a century of observations, one may quantify the orbital expansion of the moons, that are related to Saturn's k_2/Q

Without Cassini-ISS data

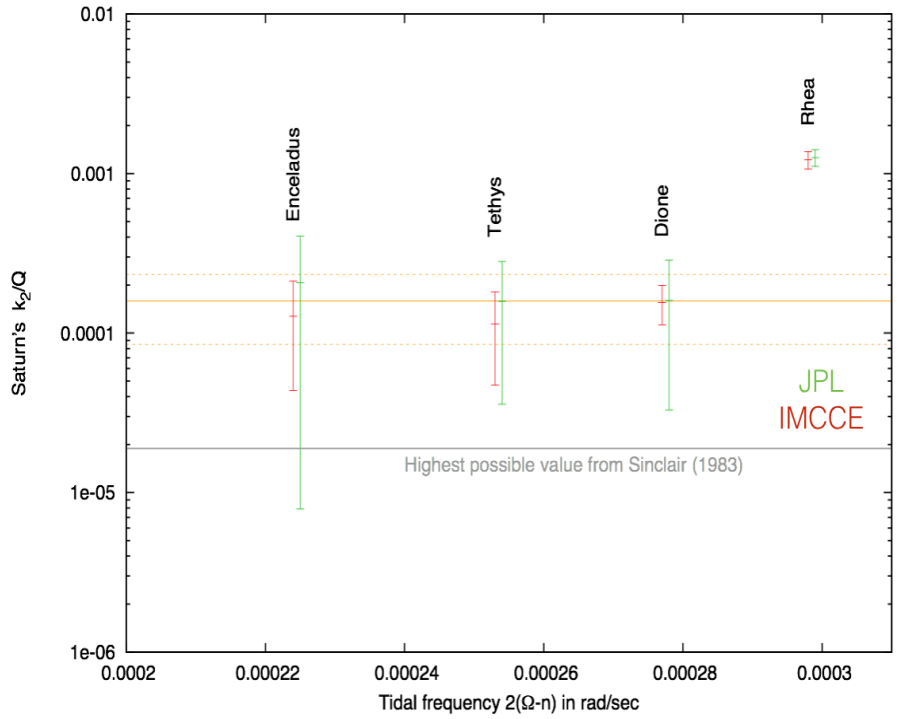


Lainey et al. (2012):

$k_2/Q = (2.3 \pm 0.7) \times 10^{-4}$

(i.e. Saturn's Q = 1682 +/-540)

With Cassini-ISS data



Lainey et al. 2017:

Confirmation of low Saturn's Q

What more can be done with astrometry?

We still have not determined:

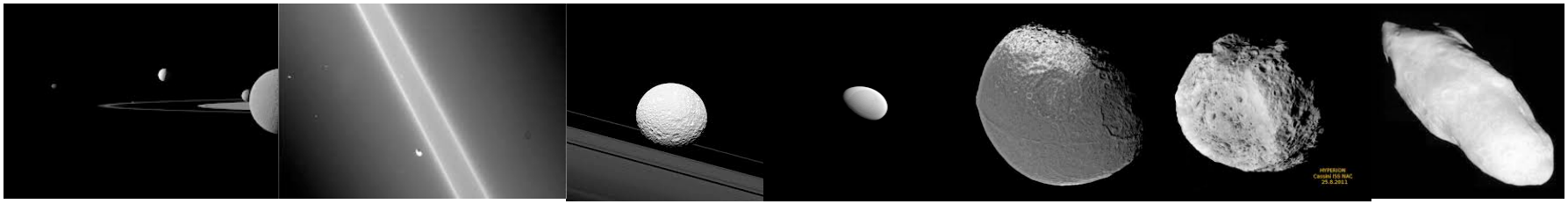
- what is the main source of the huge tidal dissipation in Saturn
- how much heat is currently generated inside the whole Enceladus

Ongoing activities using astrometry:

1- Determine properly the tidal frequency sensitivity of Saturn's k_2/Q (i.e. try getting k_2/Q at Mimas' and Titan's tidal frequencies)

2- Try estimating Enceladus' k_2/Q from its orbital motion

1 and 2 will rely on a global inversion of all data (RS and astrometry) and introducing all moons (inner, main and coorbital)



Conclusion:

Acknowledgments:

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